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MOLECULAR COMPUTING

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ABSTRACT: *Molecular computers are systems in which molecules or macromolecules individually mediate information processing functions. Molecular computing provides an alternative to computing using silicon integrated circuits. It aims at developing intelligent computers using biological molecules as computational devices. It is a promising means of unconventional computation owing to its capability for massive parallelism. It offers to augment digital computing with biology-like capabilities. This paper provides a brief introduction to molecular computing.*

KEY WORDS: *molecular computing, molecular electronics, molecular programming, DNA computing*

I. INTRODUCTION

Conventional computing uses transistors and binary logic for performing operations. However, increasing the number of functional units or speed faces inherent limitations in the number of transistors that can be put in one chip. We therefore seek using molecules as a means of computation. Molecular computers are made of proteins and other molecules rather than silicon integrated circuits (ICs). Traditional computing is compared with molecular computing in Figure 1 [1]. Molecular computing is the science that uses individual molecules to build computer programs. It is the encoding, manipulation, and retrieval of information at a molecular level. It is one of the subfields of natural computing and is sometimes referred as DNA computing. It is an interdisciplinary field that uses individual molecules as microscopic switches. It requires the collaboration of polymer chemists, device physicists, electrical engineers, biotech researchers, and futurists. The objective is to produce a von Neumann-type of computer in carbon rather than in silicon because carbon chemistry facilitates the construction of smaller and faster computing devices [2]. Carbon appears to be the element of choice for molecular computing, just as silicon is used for conventional computing. Molecular computing is often made of DNA, RNA, or other bio-molecules. A given computational problem is encoded into DNA like strings which are mixed in a test tube. The computational method has high parallel processing capability [3].

II. ADVANCES IN MOLECULAR COMPUTING

An important feature of molecular computing is that it is context-dependent; inputs are processed as physical structures rather bit by bit as in conventional computing. Due to this, molecular computers are suited for processing sensory inputs such as pressure, temperature, and light. Conventional computers handle such tasks poorly [4] Molecular computing provides several ways of solving difficult mathematical problems. Researchers have recently characterized molecules capable of acting as electronic switches and memory and organic molecules that act as electronic devices. They have initiated a new era of molecular electronics based on organic molecules [5]. Several types of molecular switches have been demonstrated. Taking advantage of the small size of molecules within a nanocell, elementary logic devices such as an inverter, a NAND gate, an XOR gate, and a 1-bit adder have been simulated [6]. A team of French scientists have built the first molecular computer using polymers to store data, making each bit 100 times smaller than with current data storage [7]. They will have a lot of challenges scaling-up.

III. APPLICATIONS

Molecular computing has shown great promise in several applications including drug delivery and molecular communication. It is a powerful tool for the development of massive parallel computation. A promising area of application of molecular computing is nanotechnology because constructing nanoscale structures requires computation at the molecular level [8]. Due to size limitations, traditional electromagnetic communication systems cannot be applied to nanonetworks. Molecular computing also has a potential value for building inference engines and expert systems [9].

IV. BENEFITS AND CHALLENGES

The main benefit of molecular computing is the potential to pack vastly more circuitry onto a microchip than silicon will ever be capable of. Molecular computers process information encoded in molecules, not in electrical signals. Since molecules are only a few nanometers in size, it is possible to make chips containing billions of components. Molecular devices (with each molecule operating as a switch) are astonishingly easy and potentially cheap to make. For molecular computing to be practical, it must be able to solve problems of a large size. Few molecular electronic devices can beat silicon devices on both speed and energy efficiency. Lab experiments on molecular computers are currently expensive, inefficient, and unreliable. Hoping that molecular electronics will quickly catch up with the fast-moving advances of silicon has led to disappointment. Despite these challenges, molecular computing has a promising future.

V. CONCLUSIONS

Molecular computing as a field is in an early but rapid stage of development. It must be evaluated against the performance of conventional silicon-based computing. Although the field has been gaining a lot of traction, it is currently not possible to build these computers at a large enough scale to substitute silicon. The bold promise of replacing silicon with molecular components is yet to come to reality. For more information about molecular computing, one is cordially advised to consult [10,11].

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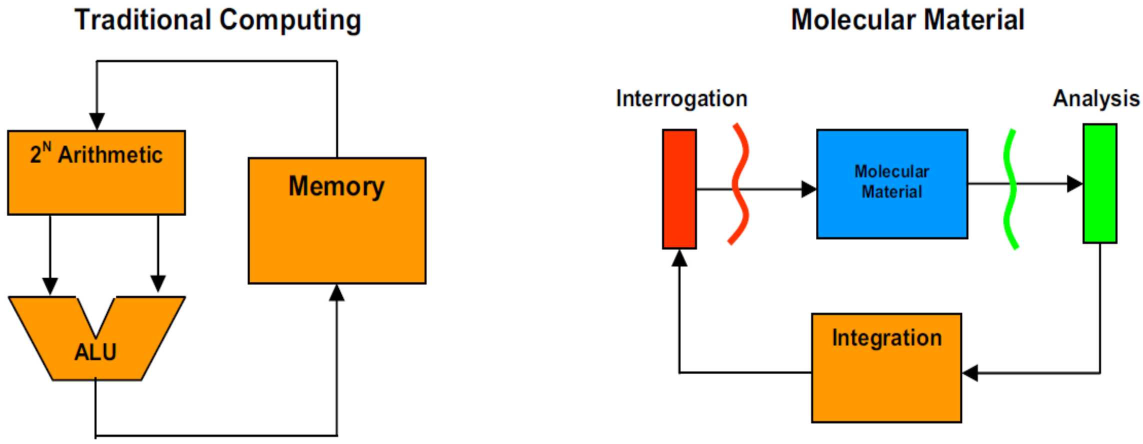

Figure 1 Traditional computing compared with molecular computing [1].